better because of their having intermingled with his.

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*EDWARD ORTON, GEOLOGIST.**

IT was in the autumn of 1869, just thirty years ago, that I first met Dr. Orton. In that year the Second Geological Survey of the State was inaugurated under the directorship of the late Professor Newberry; Governor Hayes named Dr. Orton as one of the two principal assistants for which the law made provision; and it was my own privilege to be accepted, at the same time, as a volunteer aid. In the arrangement of duties Dr. Orton took charge of work in the southwest quarter of the State, and Dr. Newberry gave chief attention to the northeast quarter. Being assigned to Newberry's corps, I had no opportunity to meet Dr. Orton until late in the season, when I had the good fortune to be bidden to attend a conference of the chiefs at Columbus. While on the journey from Cleveland, Newberry prepared me for the meeting by sketching the quality and character of his colleague—a man without guile, direct in his conversation, and absolutely transparent as to motive. The simplicity of manner which would impress me at the start was not of manner merely, but was a fundamental trait coördinate with, and not contradicted by the wisdom which made him a man of affairs. His sensitive conscience making him peculiarly careful to adhere to the facts of observation, he was cautious and conservative in all his geologic work.

Newberry's description naturally made a strong impression, and in the conference that followed it is probable that I gave as much attention to the man as to the subjects of discussion. Certain it is, that the geologic themes have vanished from my memory, while the picture of the man remains. In later years, as we met from time to time, as I listened to his voice in public address or read the papers that emanated from his pen, I was able to add here and there a detail which Newberry's sketch had failed to delineate, but no line of it was ever erased, and Orton has remained for me one of the safest and most open-minded of investigators and the simplest, kindliest, and most lovable of men.

To what extent considerations of historical fitness may have determined the arrangement of to-day's exercises I do not know, but certainly there was peculiar propriety in giving first place to Orton's work as an educator. During the first half of his period of intellectual activity education was the primary theme, and it was only in later years that geology assumed prominence. We are told that his first geologic observation was undertaken with the distinct purpose of increasing his efficiency as a teacher of geology, and in his early acquaintance with rocks and fossils his point of view was educational. Interest in geologic studies for their own sake was a matter of development, and many years elapsed before it assumed control in the determination of his fields of activity. This peculiarity of his introduction to the science in which he finally achieved distinction had much to do with the quality of his scientific work and scientific writings.

It determined, in the first place, that he should not specialize at the beginning of his career. In geology, as in medicine, there are general practitioners, broadly versed in the principles and particulars of the science, who are prepared to undertake and conduct investigations of great variety; and there are specialists, each devoted to some minor branch of the general subject, in which he works intensely and exhaustively. The specialist, restricting his attention thus to

* Read at a Memorial Meeting, Columbus, Ohio, November 26, 1899.

a narrow field, is almost necessarily a somewhat narrow man, and while his concentration of effort may lead to important results altogether unattainable by the general student, he is subject to great danger from lack of balance. The teacher of geology is compelled by his vocation to acquaint himself with all branches of the science, so that his view is necessarily broad, and if he is also an investigator in a special field he is comparatively exempt from the recognized dangers of specialization. Orton's early work as teacher and observer gave him the broad view. When he first became known to the scientific world as an investigator he was recognized at once as a general practitioner or all-around geologist, and when, in later years, his field was somewhat restricted and he became an expert in a special department, there was no danger that his narrow view would blind him to the recognition of the broader relations.

In somewhat similar way the method and phraseology of his scientific writings were determined by the compound character of his career. As a teacher he was called upon to present the principles of his science to beginners in scientific study; as a lecturer to popular audiences he was accustomed to the communication of scientific ideas in untechnical language; and as executive officer of academy, college and university he had constantly to deal with men of affairs untrained in the technicalities of science. Thus ever in touch with the lay mind he was in no danger from the literary pitfalls which beset the recluse and the specialist. He wrote for the people in language which they could understand, and even when presenting his scientific conclusions to brother geologists he found little need for those technical terms which are so apt to render science unintelligible to the general reader.

The manner of his introduction to the work of scientific investigation had its influence also on the quality of his work. As most of my audience are well aware, scientific investigation, or the endeavor to understand nature, consists of two parts, observation and theory. We open our eyes to the facts, or phenomena, as they are called, of nature, and make record of what we see, and then we endeavor to explain the phenomena by discovering how they have come to be. We observe and we theorize. But while observation and theory may logically be distinguished, in practice they must be intimately combined or the best results are not secured. There are, indeed, observers who take little cognizance of theory; but the best observers have theory constantly in mind, and through consideration of the relation of their facts to theory have their vision sharpened and their attention guided to those things which are most important. And there are theorists, too, who are indifferent to facts, soaring untrammeled in the realms of imagination and speculation. But the successful theorist tests every hypothesis by scrupulously comparing it with the phenomena to which it pertains, and modifies or rejects it when he discovers a discordance. It is by the observer who is also a theorist, and the theorist who is also an observer, that real progress is achieved.

As a teacher Orton derived from the literature of geology a body of theory which he complemented, so far as practicable, by personal observation of the rocks, minerals and fossils that lay within his reach. Thus he trained himself early to habits of observation, and in all his later work kept in close touch with the phenomena of nature. As an investigator he generalized freely and did not shrink from the propounding of theories, but all his theories were so broadly founded upon, and so faithfully verified by, the phenomena of observation that they came to the world as demonstrations which could not be gainsaid.

This far we have considered only Orton's work in pure science, but his work in applied science was of equal or greater importance, and it was in this field that his personality was most marked. I trust that you will bear with me in another digression at this point, for his life serves to illustrate certain peculiarities of the relation of man to science which are not always kept clearly in view.

It is a matter of common understanding that scientific knowledge, or knowledge of nature, is the foundation of the material progress of the race, but the method through which it serves this purpose is perhaps less broadly understood. Through research the body of 'natural knowledge' has been created and is constantly increased. This body of knowledge is a storehouse from which men may draw that which they find useful, and from which they do, in fact, make drafts at every stage of progress. But the store of knowledge grows quite independently of the drafts which are made upon it. The utility of the individual grains of knowledge is not foreseen, and their accumulation is always much faster than their utilization. So far as we may judge the future by the past, only a small portion of the garnered knowledge will ever find practical application, and thus, from the purely utilitarian standpoint, there is an immense waste of energy in the prosecution of research. This only illustrates the general fact that mankind is a part of nature, for in nature the ways of progress are ever wasteful. The acorn is nature's device to prevent the extermination of the oak, and an oak tree in its long lifetime produces a myriad of fertile acorns, but only one of these, on the average, escapes all the dangers of immaturity so as to develop a perfect tree ; the others fail for lack of opportunity, and, so far as the continuance of the species is concerned, are wasted.

The gathering of this great store of natural knowledge, only part of which can serve the purposes of mankind, is called pure science. The utilization of such portion as may be found available constitutes applied science. If the practical ends of applied science constituted the only motive for labor in pure science, mankind would be appalled and discouraged by the enormity of the waste ; but, fortunately for human progress, another motive exists in the love of knowledge for its own sake.

Every activity which is so often repeated as to become habitual affects mental constitution and may result in a corresponding sentiment, appetite or instinct, which in turn becomes a motive for the activity. Take, for example, the fundamental act of eating, which is essential to preservation of life and is common to all animals. There has been developed in connection with it a desire to eat, or appetite, which for most sentient beings is the actual motive, there being no perception of the relation of food to life. Men associated in communities find advantage in the classification and division of labor so that each shall perform some one function for others as well as for himself, being repaid through equivalent service by others. In order to exchange labor, or the products of labor, good faith is necessary, and coöperative living has accordingly developed the sentiment of honesty. Moreover, as industrial organization makes each individual continually work for others more than for himself, there is developed in him a sentiment impelling him to do for others, the sentiment of altruism. Again, the importance of social aggregation in the evolution of all phases of human culture has led to the creation of great nations, and national existence has engendered national sentiment, the sentiment of patriotism, but the masses actuated by patriotism as a motive have little conception of the value of aggregation as a factor in human development.

In a similar way scientific research as an essential to material progress has developed its own sentiment, the scientific sentiment, or the sentiment of acquiring knowledge for its own sake, and this is the motive of pure science. As honesty, altruism and patriotism are sometimes carried to absurd limits, so as even to oppose the ends they normally tend to promote, so the scientific sentiment is liable to perversion; and there are not wanting scientists so devoted to the acquisition of knowledge that they are impatient of its application, and look with disdain on other scientists who strive to discover its uses.

In the application of natural knowledge to human uses material gain is usually in sight, and this supplies a motive so distinct from the unselfish sentiment of science that the same individuals are rarely votaries of both pure and applied science. Taking an illustration from the branch with which I am most familiar, the mining engineers, occupied with the application of geologic knowledge and actuated primarily by the motive of material gain, are a distinct body of men from the geologists proper, occupied with the acquisition of geologic knowledge and actuated primarily by the scientific sentiment. There are, indeed, individuals who perform both functions, but as compared to the general body they are rare exceptions. Such an exception was Edward Orton, and he stands prominent among geologists as one actuated by altruistic motives not only in the acquisition of knowledge but in its application. Selecting, by preference, the geologic problems connected with the useful minerals stored in the strata of his State, he carried his work not merely to the inductions and theories of pure science but to practical utilitarian applications, and these were freely given to the community he served. Through official reports, through the columns of newspapers, and through personal conversation he imparted not only statistical information and general principles concerning the occurrence of ores and mineral fuels, but practical and timely advice as to their exploitation and conservation. Employed by the people, he labored for the people, and he gave them the bread for which they asked.

Orton's work in geology, so far as it is a matter of record, is largely connected with the survey of this State [Ohio.] For thirty years he was an officer of the State, and though not continuously engaged in its service nor always compensated in money for the work which he performed, it is believed that he devoted more time to its exploration and survey than any other geologist, and that his knowledge of the distribution, qualities and structures of its rocks was correspondingly intimate and comprehensive. His reports are so numerous and extensive and pertain to so wide a range of topics that I shall leave their enumeration to the biographer and bibliographer* and content myself with a simple outline.

An assistant geologist under the directorship of Professor Newberry he began work in 1869 in the southwest quarter of the State, called the Third District, and his labors were confined to this field for a number of years. Gradually, however, they were extended to coal fields farther east, and after the year 1882, when he practically assumed the functions of geologist in chief, the entire State was within his purview. He was also engaged for shorter periods in the investigation of oil and gas fields of Kentucky, Indiana and New York, and he made reports to the United States Geological Survey and to the Eleventh Census of the United States on various economic resources of Ohio and Indiana. His contributions to pure science were in part published by the Geological Society

* A list of scientific papers will appear in volume 11 of the Bulletin of the Geological Society of America.

of America and by various scientific journals.

Among his writings are many discussions of the character, sequence, extent and arrangement of the geologic formations underlying the State, and also of the deposits of drift which mantle the surface. He described in detail the geologic features of many counties, and he worked out and published the structure of most of the coal fields of the State, discussing not only the relations and extent of the seams, but their practical qualities. During the last two decades he gave great attention to the development of petroleum and natural gas, treating the scientific and practical aspects of the Ohio fields with a thoroughness which I believe to be without parallel. At various times he studied and wrote upon the building stones, limestones, iron ores, rock water, gypsum and clays of Ohio and other States, elucidating the geologic relations and usually pointing out also their economic bearings.

From the mass of material thus accessible I select for special mention a single contribution to pure and applied science, choosing the one with which his name is most frequently associated by brethren of the hammer at home and abroad. I refer to his study of the relation of gas, oil and brine in subterranean reservoirs. It was well known that the flow of oil from a well is often preceded or accompanied by the escape of gas; it was known that the life of an oil well was often terminated by the influx of water, and that this water, when derived from the same reservoir as the oil, was highly charged with mineral matter; it was known that the static pressure of natural gas in a well was usually the same for all wells of a group or district, and independent of the altitude of the opening; and partial explanations of these facts had been suggested by various students; but it remained for Orton to formulate a comprehensive theory explaining all the phenomena, and then, testing it by comparison with a series of measurements and other observations in the gas and oil fields of northern Ohio and Indiana, to place it on a sure and enduring basis. Like many another result of elaborate and successful investigation, his theory, when stated, appears so simple as to be almost axiomatic, and one is tempted to wonder why the common sense not only of geologists but of all concerned in the development of petroleum and natural gas had previously failed of its attainment; and yet nearly every part of it has been at one time or other the subject of attack and controversy.

Each stratum of porous rock containing a profitable store of oil and gas is sealed above by some impervious layer, so that fluids cannot escape upward, though it may communicate freely with the surface of the ground at a distant point, if only the communication involves an inverted siphon equivalent to the plumber's trap. Under these conditions the stratum constitutes a reservoir in which three fluids arrange themselves according to gravity; gas occupies the pores of the upper part, and is succeeded downward by oil, which in turn rests upon water. If the stratum reaches the surface of the ground at a place lying higher than the reservoir, the water supplied to it by rains exerts a pressure, in accordance with the familiar hydrostatic law, on the water in the reservoir, and this is communicated to the oil and gas. The gas is compressed until its elasticity counterpoises the weight of the column of water. If, now, a well is drilled so as to tap the reservoir at its highest point, gas rushes forth, being forced out by the pressure of the water. If a well reaches the reservoir in the zone occupied by oil, the oil is similarly forced upward, and may be discharged at the surface in case the pressure from the water is sufficient. If a boring taps the reservoir

still lower, it reaches water, which is similarly forced upward and may flow at the surface. The water is always a brine, because, occupying a closed reservoir, it has no circulation and has been dissolving for ages the soluble minerals contained in the rocks; and it is thus contrasted with the potable waters of artesian wells, which contain comparatively little mineral matter, because they are parts of an underground circulation and their sojourn within the rocks is comparatively brief. An ordinary artesian water does not rise in wells everywhere to the same height, the pressure, or head, diminishing as distance increases from the source of supply; but the stagnant brine underlying a body of petroleum is everywhere subject to the same pressure, and will rise to the same height in any well to which it has access. This principle is intimately related to the pressure under which gas escapes from a well and its knowledge has been found of great practical value to the natural gas industry.

It follows from the theory, and it is also a matter of observation, that as the gas in a reservoir is drawn off through wells, the underlying oil and brine rise to take its place, and when the local store of gas has been exhausted, the wells either produce oil or are flooded by brine.

With the demonstration of this theory the earlier idea, that gas was forced outward merely by its own elasticity, and that it was generated in subterranean laboratories from fossil organic matter as rapidly as it escaped, was completely disproved. It became evident that the supply of gas in each reservoir was definitely limited; that if once exhausted, it could never be restored; that economy was required in the use of natural gas, as with any other resource; and that the folly which permitted it to escape freely to the atmosphere was also a crime. That such criminal and disastrous folly was actually perpetrated in most of the gas fields of northern Ohio and central Indiana was not the fault of Dr. Orton, who early sounded the note of warning, and strenuously combated the infatuation of the well owners.

Of the high esteem in which Orton was held by his colleagues in scientific labor you are already aware. The Geological Society of America, an organization including the leading geologists of the continent, chose him as its president, to serve for the year 1897; the American Association for the Advancement of Science, foremost in importance among American scientific bodies, called him to the chair of its geologic section in 1885, and bestowed its highest office in the last year of his life. Even in his own country he was not without honor.

G. K. GILBERT.

ADDRESS OF THE PRESIDENT BEFORE THE AMERICAN SOCIETY OF NATURALISTS.*

BEARING in mind that we have with us this evening representatives of all branches of natural science, it seems better that I should not attempt to give here a sketch of the progress of botany nor discuss the special problems which botanists are trying to solve. Botany is certainly progressing, but progress is not hastened by stopping too frequently to consider just how much progress has been made. As far as questions of botanical research are concerned the past year has not been marked by any startling discovery, but it has been rather a year of transition, and the work done may be expected to bear mature fruit later. The most striking feature of the past year in our own country has been the publication of a remarkably large number of treatises of an educational character in which the results of recent botanical work have been presented in a fresh and attractive form, but this is evidently not an occasion on which

* New Haven, December 28, 1899.